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Bringing 100 million-year-old marine microbes back to life

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100 million years ago – in the age of the dinosaurs, prehistoric microbes had been trapped in the subseafloor sediment. When they were brought back to the lab, they were found to still be alive. Why were they not fossilized? How were they revived? This work reveals the mystery of how microbial life in deep and starved subseafloor sediment has survived with much more left to be uncovered.

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The Earth's entire surface is inhabited by life, but what about what lies beneath, in the subsurface? In the past, we thought of the deep subseafloor as a lifeless zone. We now know it is the "subseafloor biosphere" inhabited by a substantial percentage of Earth's microbes.

The environmental conditions in the subseafloor are as diverse as the life inhabiting it. Temperature and pressure conditions vary, and food and nutrients are not readily available across the seafloor. We therefore started with the question: could life exist where there is an extreme lack of food? To answer it, we investigated subseafloor sediments looking for microorganisms beneath the centre of the South Pacific Ocean, called the South Pacific Gyre.

On the seafloor, there are layers of sediment consisting of marine snow (organic debris 'snowing down' from the sea surface), dust, and particles carried by the wind and ocean currents. The particles fall consistently, so the deeper the layer, the older it is. With the scientific seabed drilling expedition "Integrated Ocean Drilling Program Expedition 329, South Pacific Gyre Subseafloor Life", we obtained subseafloor sediments that formed 100 million years ago. So, any microbes found within this layer of the sediment would have existed at this time. The sediments consisted of a fine grain, almost as small as microbial cells. By measuring the physical properties of the sediment, such as the size of the grains, we confirmed that the microbes were indeed packed into the grains. This tells us that these old microbes were unable to escape and any newer or younger microbes to enter into the ancient sediment.

Marine snow is the major source of food for subseafloor microbes. However, at the South Pacific Gyre, the subseafloor microbes receive the lowest marine snow supply in the world's oceans. This means that there has been almost no additional food available and no movement possible on the subseafloor, in 100 million years. The microbes' food availability at the South Pacific Gyre is far below the lowest amount of energy required to sustain the life of any laboratory-cultured microbes. So, although we found microbes in this deep, ancient sediment, we initially thought that they would be very close to being dead and may not be easily revived at all.

However, after we provided various nutrients (such as sugar and amino acids) to coax the microbes to grow in the laboratory, the microbes started eating and, surprisingly, growing! This means that they are not the dead, fossilized remains of life, but resilient living survivors of the subseafloor environment.

Although we were pleasantly surprised by these results, like true scientists, we remained skeptical and carried out further tests to see if what we observed was true. We carefully re-examined our experiments and concluded that up to 99.1% of the microbes in sediment formed 101.5 million years ago were still alive and were ready to start eating! We knew that life flourishes near the continents where there's a lot of buried organic matter, and usually about 70% of microbes found are alive. Therefore, it is truly amazing and unexpected that the extremely nutrient-poor sediment of the South Pacific Gyre had such a high rate of live microbes within it.

These results clearly showed that there are living organisms that exist in seemingly inhospitable conditions beyond the limits of what we assume is necessary for life. With our study, however, we still have not understood how exactly the discovered microbes have remained alive in such deep sediments. One way forward is looking into the genes of these microbes.

Given the extremely nutrient-limited condition of the subseafloor, life for the microbes that live there is very slow compared to those that live on the surface. From this, we could also assume that their speed of evolution would be slower as well. Using this evolutionary context, we are now interested in comparing and studying the genome sequences of the microbes to see if their DNA holds clues to their seeming immortality. Studying living organisms that are still holding on to life in their ancient environment, the subseafloor sediment, is like a time machine, playing out in real-time for us, so that we can better understand the ancient conditions on Earth.